Students' Manual of Electro-Therapeutics

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STUDENT'S MANUAL

OF

ELECTRO-THERAPEUTICS

EMBODYING

LECTURES DELIVERED IN THE COURSE ON THERAPEUTICS AT THE WOMAN'S MEDICAL COLLEGE OF THE NEW YORK INFIRMARY

BY

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Etc., Etc., Etc.

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PREFACE.

This little book is presented to the medical public, chiefly as a protest against the mysticism and charlatanry which have ever hung around the literature and practice of electro-therapeutics.

As our scientific knowledge of other therapeutic procedures developed, they gradually escaped from the thraldom of quackery. Not so with electricity. Its showiness, its instantaneous and startling physiological effects, and its name, popularly synonymous with life, have long and will long continue to make it a fashionable remedy, a cure-all for imaginary diseases, a popular placebo, a gold mine for charlatans and symptom-treating physicians, who let their patients make the diagnosis and suggest the treatment.

Never does the question, "Was my patient *cured* or did he *get well?*" arise so often as in

the practice of electro-therapeutics; other remedies are so often simultaneously employed, the treatment, as a general thing, extends over so many days or months, and so much allowance must always be made for the effect of expectant attention.

From the foregoing remarks, let not the reader imagine that the writer wishes to depreciate in any way the real therapeutic value of electricity, but the following pages are intended to narrow the subject down to the comprehension of the average student and general practitioner.

One fault of many of the already existing treatises on electro-therapeutics is, that they are too diffuse—too bulky; some containing many pages of unnecessary historical matter and perplexing minutiæ of chemical, physical, and mechanical detail, some overflowing with conflicting and barely proven physiological hypotheses, while others appear like practices of medicine—so full are they of detailed histories of cases of all kinds.

The aim of the writer has been:

First.—To present that amount of the sub-

ject of electro-physics necessary to the proper understanding of the construction and use of medical batteries.

Second.—To point out the commoner, gross physiological effects of electricity.

Third.—To outline the methods of electro-diagnosis.

Fourth.—To determine the kind of electricity and its mode of application indicated in different pathological states.

18 West 21st Street, New York.
May 22, 1884.

ELECTRO-THERAPEUTICS.

GALVANISM.

GALVANISM is a well-known form of molecular motion. It, in its simplest form, is an electrical current developed by the chemical action of a corrosive liquid on two dissimilar metals or elements. The word "current" implies motion, and motion presupposes an initial impulse. This force starting the electrical current is called the electro-motive force.

What sets any thing in motion is a loss or want of equilibrium ; hence the electro-motive force is a want of equilibrium between two dissimilar metals or elements. This want of equilibrium we call, when speaking of electricity, the difference of "potential" of the two elements. We use the word potential as we use the word temperature, and we speak of sub-

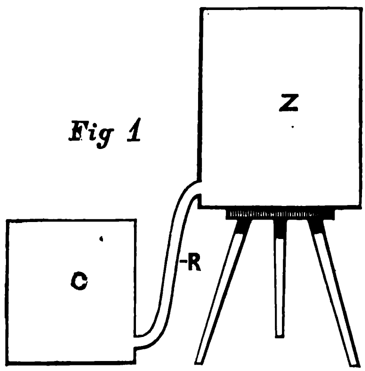
stances having a high or low potential, in the same way as we say they have a high or low temperature, or are hot or cold; both presuppose a standard of comparison which, in the former case, is the electrical condition of the earth, which is practically stationary, and in the latter case the temperature of our bodies. We call any thing warm or hot when it is of a higher temperature than our body, and the molecular motion is toward the body. We call any thing cool or cold when its temperature is lower than that of the body, and the molecular motion is from the body. So we say a body is of high potential when electricity will flow from it to the earth; such a body we call positive, and designate with a +. A body is of low potential when electricity will blow from the earth to it, and this body we call negative, and designate by a —.

These standards of comparison for potential and temperature are arbitrary, hence the terms positive and negative (+ and —), hot and cold, are relative terms only. For instance, judging by our feelings, bodies at 70° C. and 100° C. are both hot, but compared with each other the body at 100° C. is hot, while that at 70° C. is cold.

In the same way two metals may have potentials, one seventy and the other one hundred times that of the earth, and hence both be positive, and yet, really, as compared with each other, the one with the lower potential is negative to the higher, and the one with the higher is positive to the lower.

A more apt illustration is that alluded to by De Watteville, *i. e.*, to compare elements of different potentials to reservoirs at different levels; for instance, z. and c., fig. 1.

Fig 1



If these reservoirs be full of water its tendency to seek a lower level corresponds to the potential of the elements. If they be connected by a pipe we will see that the higher cistern will

commence to empty itself into the lower. A current is thus established. The force starting this current is, in one case the force of gravity, and depends on the difference of level of the two reservoirs; in the other case it is the electro-motive force, and depends on the difference of potential of the two elements.

A galvanic cell, in its simplest form, consists of two dissimilar metals (c. and zn.) immersed in a corrosive liquid. (Fig. 2.)

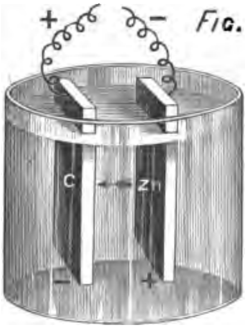


FIG. 2

For instance, let c. represent a disk of carbon and zn. one of zinc immersed in a glass jar containing dilute sulphuric acid. These dissimilar metals we call the elements of the cell. In general terms, the most easily corroded element has the highest potential and is hence called the

positive element, while the element least acted on by the fluid has a lower potential and is called the negative element. In the present case, the carbon, not being acted on at all by the acid, is of low potential and is the negative element, while the zinc is briskly attacked by the acid and becomes the positive element, the galvanic current flowing in this case through the liquid from the zinc to the carbon.

If these elements be prolonged outside the cell by conductors we have what are known as the poles of the cell, and the pole, as the element which gives off the electricity, is called the positive pole although connected with the negative element. When these two poles are brought in contact the electrical current passes from the zinc, through the liquid, to the carbon, out through the positive and back through the negative pole to the zinc. In this way we make what is termed a complete or closed circuit; when the two poles are not in contact, an incomplete or broken circuit.

Another term now demands attention and explanation—*i. e.*, resistance.

The resistance of a cell is internal and external. The internal resistance is the obstruc-

tion to the passage of the electrical current by whatever intervenes between the two elements inside the cell; the external is the obstruction offered by whatever intervenes between the elements outside the cell. This resistance of a cell depends on many factors, to explain which we will return to the old simile of cisterns. When the pipe R is long it is an impediment to the flow of the water; when the pipe is narrow the same thing happens, and if it be filled with a sponge it is easy to see that the current would be very much obstructed. Now, the two elements, zn. and c., representing the two cisterns, the fluid between them corresponds to the pipe R. The internal resistance is increased by placing the elements far apart (which is the same as lengthening the pipe between the cisterns). By making the elements small—*i.e.*, by reducing the diameter of the column of fluid connecting the elements (same as narrowing the pipe); or by interposing a poor conductor, as porous-porcelain, between the elements (same as putting sponge in the pipe). By approximating the elements (same as shortening the pipe); by enlarging the elements—*i. e.*, by

increasing the diameter of the column of fluid connecting them (same as widening the pipe); or by making the fluid as good a conductor as possible, by the introduction of an acid or salt in solution (same as taking a sponge from the pipe),—the internal resistance is lessened.

The external resistance is subject to similar variations. A long conductor, a conductor of small diameter, or a poor conductor increases the external resistance; while a short conductor, a conductor of large size, or a good conductor lessens the external resistance. The unit of resistance is called an *Ohm*, and is equal to the obstruction to the passage of the electric current offered by a copper wire 1 mm. in diameter and 48.5 metres long, or a column of mercury 1 sq. mm. in area and 1.05 metres high.

Sufficient electro-motive force to overcome an ohm of resistance is the unit of electro-motive force, and is called a *Volt*.

The current strength or working power of a cell varies directly as the electro-motive force, and indirectly as the resistance.

Thus representing the current strength by c, the electro-motive force by e., and the internal

and external resistances by ir. and er., respectively, we have the proposition enunciating Ohm's law, $c. = \frac{e.}{ir. + er.}$, and by this formula all electrical problems are worked out.

FIG. 3

In the construction of batteries several cells are used, arranged in various ways. When the positive element of one is united to the negative of the next, and so on, the cells are said to be arranged in compound circuit (see fig. 3). When

FIG. 4

all the positives and all the negatives are united, it is called simple circuit (see fig. 4). Then there is an arrangement in groups, where several cells are united in simple circuit, and

then these groups are united like single cells.

We must now study the effect of these different arrangements on the current-strength. Let e. $=$ 1, ir. $=$ 40, and er. $=$ 20, then our formula of ohm would be c. $= \frac{1}{40+20} = \frac{1}{60} = .016$, which would represent the current-strength of one cell.

Suppose, now, we take forty of these cells and unite them in simple circuit, the result is we would have what is practically one large cell, with elements forty times as large as before, and hence an internal resistance forty times less than before, and, as a natural result, an increased current-strength :

$$\text{c.} = \frac{1}{\frac{40}{40}+20} = \frac{1}{21} = .05.$$

If these same cells were united in compound circuit, the electro-motive force and internal resistance would be the sum of the electromotive forces and internal resistances of all the cells. Hence the current-strength would be increased :

$$\text{c.} = \frac{1 \times 40}{40 \times 40+20} = \frac{40}{1600+20} = \frac{40}{1620} = .024.$$

If these forty cells were united in five groups

of eight cells each, there would result a greatly increased current-strength, the internal resistance would be the same as that of five cells, with elements eight times as large, or one eighth that of a single cell, while the electromotive force would be the sum of the electromotive forces of the five groups :

$$\text{C.} = \frac{1 \times 5}{\frac{40 \times 5}{8} + 20} = \frac{5}{25 + 20} = \frac{5}{45} = .1.$$

If we increase the size of the elements, the electro-motive force remains the same, because, as has been seen, that depends on the difference of potential of the two elements, and that remains the same whatever their size. Increasing the size of the elements does, however, increase the current-strength, because it lessens internal resistance ; hence, if we increase the size of the elements in the original cell eight times, we would have :

$$\text{C.} = \frac{1}{\frac{40}{8} + 20} = \frac{1}{5 + 20} = \frac{1}{25} = .04.$$

The strength of the current is greatly influenced by the external resistance. If instead of 20 the external resistance be 2500 ohms, which is about the average resistance of the human body :

$$\text{c.} = \frac{1}{40+2500} = \frac{1}{2540} = .00039.$$

Increasing the size of the plates forty-fold would make little difference :

$$\text{c.} = \frac{1}{\frac{40}{40}+2500} = \frac{1}{2501} = .0004.$$

But multiplying the number of the cells forty-fold decidedly augments the current-strength :

$$\text{c.} = \frac{1 \times 40}{40 \times 40+2500} = \frac{40}{1600+2500} = \frac{40}{4100} = .0097.$$

If the external resistance is slight, every thing is gained by increasing the size of the plates, *i. e.*, by diminishing the internal resistance. If the external resistance is 1, we would have $\text{c.} = \frac{1}{40+1} = .024$, and if we increase the size of the plates fivefold, we would have :

$$\text{c.} = \frac{1}{\frac{40}{5}+1} = \frac{1}{9} = .111.$$

Increasing the number of the cells under the same circumstances does not increase the current-strength. If $\text{c.} = \frac{1}{40+1}$ and we use twenty cells : $\text{c.} = \frac{1 \times 20}{40 \times 20+1} = \frac{20}{801} = .024$, the current-strength of the original single cell.

When the internal and external resistances are equal, the current-strength is equally increased by making the plates larger or more

numerous; thus if c. $= \frac{1}{10+10} =$ .05, by using twenty cells:

$$c. = \frac{1\times20}{10\times20+10} = \frac{20}{200+10} = \frac{20}{210} = .09,$$

by using elements twenty times as large:

$$c. = \frac{1}{\frac{10}{20}+10} = \frac{1}{\frac{1}{2}+10} = \frac{1}{\frac{21}{2}} = .09.$$

From the foregoing formulæ it is easy to draw the deduction that, to make a battery useful—*i. e.*, to make it yield the greatest current-strength—an endeavor should be made to equalize, as nearly as possible, the external and internal resistances.

The current-strength is measured by the various physical, mechanical, or chemical effects it produces; its unit is a *veber*.

A veber is a current which will set free 0.115 c.c. (approximately) of hydrogen by the decomposition of water at 0 c. and 7.60° mm. of pressure; or the quantity produced by one volt through one ohm of resistance. This current strength is seldom used in applications to the human body, hence the milliveber is generally accepted as the unit of current-strength in medical electricity.

A well-known power of galvanism is, when circulating through a coil of wire, to cause deviations in a neighboring magnetic needle. On this principle the galvanometer is constructed. A galvanometer consists essentially of a coil of wire, through which the current passes, in the neighborhood of which is a magnetic needle suspended on a pivot. The dial which the point of this needle traverses is generally divided into 360 equal degrees. Such a galvanometer is worse than useless, because it in no way tells the strength of the current passing. The reason is this. While thirty cells of a battery may deflect the needle of an ordinary compass 25°, it by no means follows that sixty similar cells will deflect the same needle 50°. The first few degrees of deflection are caused by a very weak current; the more the needle deflects from its normal position, the harder it is to move it, and the slower it deviates. Hence, while the first cell may cause a deviation of 10° or 12°, each additional cell moves the needle less and less.

It follows that a graduation having degrees of equal length all the way round can be of no

scientific use. The graduation should show the strength of current passing, and hence the degrees should be at first coarse, becoming, on either side of the needle, progressively finer and finer.

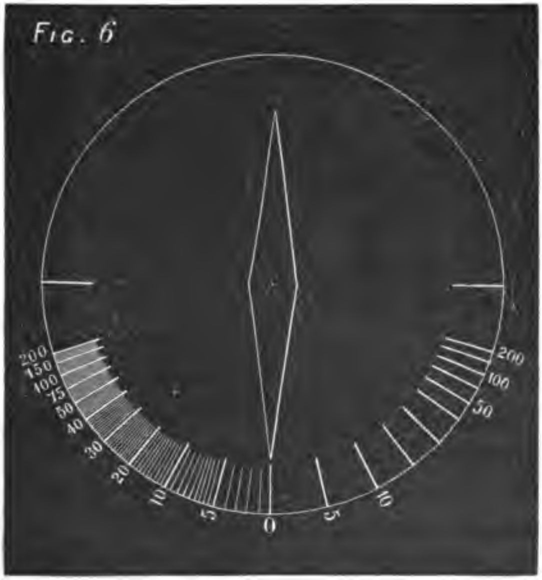


Fig. 6

The best graduation is that into tenths of millivebers—*i. e.*, a galvanometer where the needle, when a given resistance is in circuit, by pointing at a certain number on the dial, shows

that a current so many millivebers strong is passing. A galvanometer should be graduated by passing, through a known resistance, the current of a battery, the cells of which have an equal and known electro-motive force.

In this way one is enabled to calculate exactly when one, two, or three, etc., millivebers are passing, and to mark them on the dial.

The best way to measure electro-motive force is as follows: Take a cell of known electro-motive force and connect it with a galvanometer, and note exactly the amount of deflection that occurs. Then connect the cell or cells to be tested with the galvanometer, and again note the amount of deflection of the needle. The elecro-motive forces will be proportionate to the deflections of the needle.

The external resistance is regulated, and, under varying circumstances, made to correspond with the internal, by means of an instrument known as a *rheostat*.

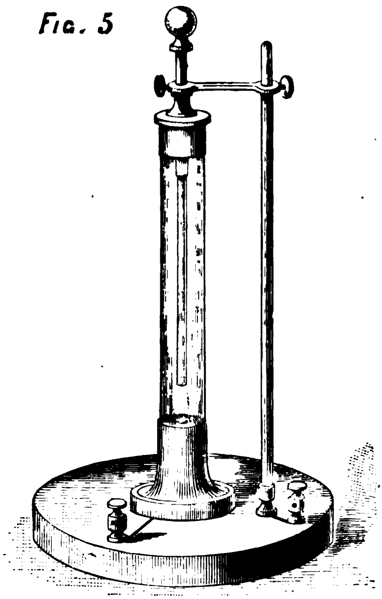
A rheostat is an appliance by means of which we can place a certain length of a conductor of known and uniform resistance in circuit.

The commoner are coils of insulated German-

silver wire or a column of water. The water rheostat is simpler, cheaper, and more generally useful.

It consists simply of a glass tube filled with

Fig. 5



water, or some solution, through which the current is made to pass from a rod, sliding in the cover of the tube, to a metallic button at the bottom of the tube; the resistance in the rhe-

ostat varying according to the size of the column of fluid and its conductibility.

To measure the internal resistance of a cell or battery, place in its circuit a galvanometer, and note the current-strength as denoted by the deflection of the needle; then put in the circuit, by means of a rheostat, sufficient resistance to diminish the current-strength one half, and it will be seen that the amount of resistance inserted into the circuit represents exactly the internal resistance of the cell.

$$\text{c.} = \frac{\text{e.}}{\text{r.}} = \frac{1}{1} = 1.$$

If, now, by interposing a certain resistance we cut down the current-strength one half,

$$\text{c.} = \frac{\text{e.}}{\text{r.}} = \frac{\text{e.}}{\text{er.} + \text{ir.}} = \frac{1}{2} = \frac{1}{1+1};$$

hence, as the internal resistance is unchanged, ir. = er.

PRINCIPLES TO GUIDE ONE IN CONSTRUCTING A BATTERY.

The general rules to follow are, in the first place, to acquire the greatest possible electromotive force which is secured by placing two dissimilar metals in corrosive liquid which acts vigorously on one; little, if at all, on the other.

This is accomplished by the use of zinc and carbon as elements, sulphuric acid as a fluid.

The second rule to follow is to make internal and external resistances proportionate.

When a battery is needed for ordinary galvanic applications—*i.e.*, where the resistance of the human body, about 3000 ohms, comes into circuit, this is accomplished by using *many small* cells of good electro-motive force and high internal resistance coupled in compound circuit.

For instance if $\frac{\text{e. } 2}{\text{ir. } 15 + \text{er. } 3000}$ or 0.0006 represent the current-strength of one cell, by using sixty of these cells we will get :

$$\text{c.} = \frac{2 \times 60}{15 \times 60 + 3.000} = \frac{120}{3900} = 0.03.$$

When a battery is to be used for electrolytic purposes—*i. e.*, when a small portion of the human body, having a resistance, say, of 100 ohms, is included in the circuit, a few moderately large cells coupled in compound circuit give the best results. For instance, if $\frac{\text{e. } 2}{\text{ir. } 10 + \text{er. } 100}$ $= 0.018$ represent the current strength of one cell, that of ten cells would be :

$$\frac{2 \times 10}{10 \times 10 + 100} = \frac{20}{200} = 0.1.$$

When it is wanted simply to heat a platinum

wire to whiteness, as in a cautery battery, the external resistance is very slight, and we get the most current-strength from a few cells, with large elements, very near together—*i. e.*, with a small internal resistance. If $\frac{e.\ 1}{ir.\ \frac{1}{2} + er.\ \frac{1}{2}} = \frac{1}{1} = 1$ represent the current-strength of one cell, that of four cells would be 1 :

$$\frac{1 \times 4}{4 \times \frac{1}{2} + \frac{1}{2}} = \frac{4}{2\frac{1}{2}} = 1.6.$$

Taking all things into consideration a "single-fluid" cell is the most generally useful, and of such cells a modified Smee is the best—*i. e.*, zinc and carbon elements in a solution of bichromate of potash in dilute sulphuric acid. The fluid and the zinc of the cell can be readily replaced when exhausted. The cell has a high electro-motive force, is pretty constant, is not very easily "polarized,"[1] and is not harmed by being "short-circuited."[2]

[1] A cell is polarized when, owing to the chemical action, bubbles of hydrogen collect at the negative, bubbles of oxygen at the positive element and, hydrogen being positive to oxygen, an electrical current is set up from the hydrogen to the oxygen. This is in a direction opposite to the original current, will weaken, and may neutralize it. Various methods are employed to prevent this action, which, in this instance, is accomplished by the bichromate of potash, which combines with the hydrogen.

[2] A cell is "short-circuited" when, as the word implies, the con-

A few words now about the construction of a battery; and reference will be made exclusively to portable batteries for ordinary galvanic applications. Small cells of vulcanite or glass are arranged in a tray of some sort and two thirds filled with the so-called "red-acid" fluid.[1] When moved, spilling of the fluid must be prevented by a diaphragm covered with rubber, which tightly covers the cells. An arrangement is effected by raising the cells or lowering the elements, so that the zinc of one couple and the carbon of the next can be immersed in the same cell. To the upper ends of these elements are attached wires, which, as they cross and recross each other, must be *very* thoroughly insulated. These wires pass to a *collector*—a contrivance to enable one to use the current generated from one or several cells as is seen fit.

ductors completing the circuit are short, or have a smaller resistance than the cell was built for. For instance, the cells of a Leclanchè battery, which have a large internal resistance, and which are made for the purpose of overcoming large external resistances, will be exhausted in a few hours if the circuit is completed by a wire or if, after using the battery, the electrodes are left in contact; while a fluid cell will last as well when worked on a short as on a long circuit.

[1] Add one part of commercial sulphuric acid to ten parts of cold water, to which mixture, when cold, add one part of finely powdered bichromate of potash, and mix well.

The simplest kind is a *dial* collector (see fig. 8), which consists of a circle of buttons, connected directly with one set of elements, upon which a metallic bar can be made to impinge. By means of this bar connection is established between the button upon which it impinges, through the bar, to the metallic pivot upon which it revolves, which is connected by wires with the *commutator* (see fig. 7).

The arm of the dial collector must be so broad that it will impinge on one button before it leaves another, thus avoiding interruptions in the current. If the battery contain many cells, two dial collectors should be used, so that a graduated increase or diminution of the current may be made.

Let each button represent one cell or, what is not as good, let each of the buttons of one dial represent 2-5 cells, while the buttons of the other are connected with single cells.

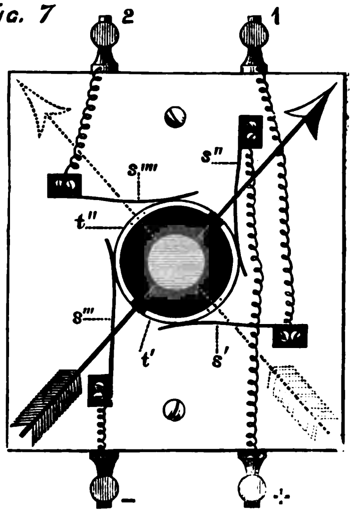
The advantage of this arrangement is obvious as it enables you to employ any number of cells, from one to the full force of the battery.

One more appendage should form a fixture on every battery, and that is the *commutator* or

pole changer. This is a contrivance by means of which the polarity of the electrodes may be changed while they remain in situ.

The accompanying cut will show that this is accomplished by means of a "split button,"

FIG. 7



which consists of a disk of hard rubber revolving on a shaft, which is bound with a tire of brass (t′ t″) in which two breaks occur. Four springs (s′ s″ s‴ s⁗) press firmly against this tire in such a way that two of them, when the but-

ton is rotated, jump over the gaps and come in contact with the opposite half of the tire.

For instance, in fig. 7 the current leaves the positive pole + traverses spring s″, runs around the right half of the tire t′, through the spring s″″

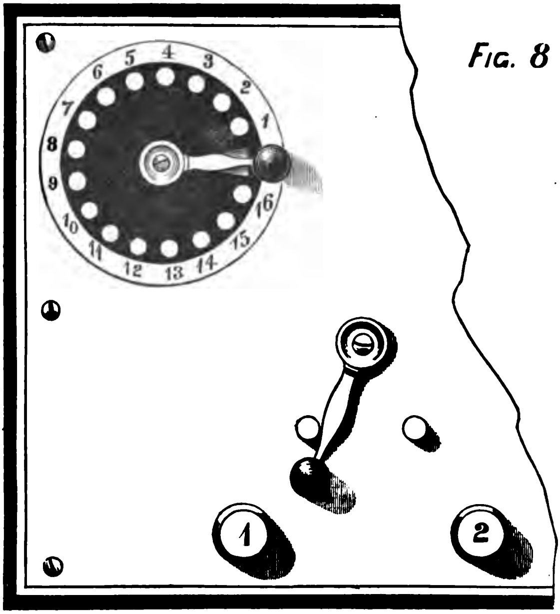


FIG. 8

to the binding post 1. Then, if the circuit be closed, across to post 2, back to spring s″″, around the left half of the brass tire t″, through

the spring s''' to the negative pole. This will make 1, the positive pole, 2, the negative pole. If the button is turned to occupy the position indicated by the dotted arrow, it is easy to see the polarity of the posts will be reversed—*i.e.*, the current will run from + directly to 2 and from 1 straight back to —.

This split button is covered, in most batteries, and is turned by a handle or winch which should always point, as does the arrow, in fig. 7, toward the positive pole. There should be two binding posts (1 and 2), which should be made to hold the rheophores or conductors by means of screws.

Dial collectors, a commutator, and two binding posts are the only *fixtures* that should be on a portable galvanic battery.

Do not combine a galvanic and faradic battery in the same case.

Of ACCESSORIES to a galvanic battery there are several which are very important, but which, I think, should never be permanently incorporated with the battery.

First, a galvanometer. If a good[1] galva-

[1] By "good galvanometer" is meant one accurately graduated in milli- or tenths of milli-vebers.

nometer can not be obtained, do not get any. To use the galvanometer, connect it by a short, large, copper wire to a binding post on one side, while to the opposite side attach one of the rheophores.

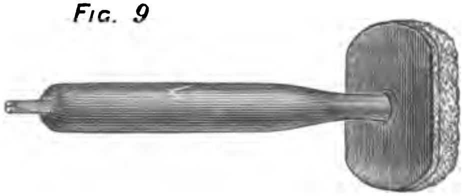
In the second place there should be a plain rheostat holding a column of water about twenty centimetres high and about one centimetre in diameter. This is put in circuit in the same way as the galvanometer, and, when the whole column is in circuit, will cause a resistance of about 2,000 ohms, sufficient for all practical purposes.

RHEOPHORES are flexible conductors connecting the binding posts and electrodes. If scientific accuracy is desired they should be made of insulated copper wire. For ordinary purposes the insulated cable made of tinsel thread is all-sufficient. It is more flexible than the copper wire and will not kink, but it is a poor conductor, and, by its resistance, wastes much of the current.

ELECTRODES in electro-therapeusis are the termini of the poles of the battery from which the electricity passes into the body. Of elec-

trodes, special forms will be spoken of when speaking of special applications. The commoner forms are flat electrodes of various sizes, consisting simply of a sheet of flexible metal or gauze, covered by a flat sponge and backed by rubber cloth, and smaller ones affixed to a handle. These latter are best made of various-shaped and sized disks of compressed gas carbon, covered with sponge, and fitting, by a screw, to wooden or vulcanite handles, to the other end of which are attached the rheophores; conduction through the handle being accom-

FIG. 9



plished by means of a metallic rod, into one end of which the tip screws, and to the other the rheophore is fastened.

The handles should be about twelve centimetres long and about two in diameter, and of a variable cylindrical shape.

Have all the screws of the tips of uniform

size, so they may be used on all handles indifferently.

An interrupting handle is an indispensable article. This consists of an arrangement by means of which the current can be made or broken, closed or opened, at will by the hand of the operator, the electrode remaining in situ. The simplest form is that depicted in fig.

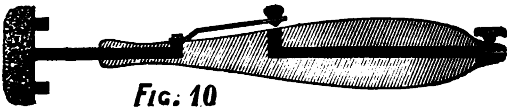


FIG. 10

10, where, by means of a spring, the circuit can be closed or opened by the pressure of the thumb. This, I think, is all the interrupting contrivance needed in connection with a galvanic battery.

The PHYSICAL EFFECTS of the galvanic current are the production of heat and light. The MECHANICAL EFFECT is the prodution of osmosis, which takes place in the direction of the current, *i. e.*, from the positive to the negative.

The CHEMICAL EFFECT of the galvanic current is what is known as electrolysis, *i. e.*, a splitting up of chemical compounds into their

component elements, the acid element being set free at the positive, the alkaline element at the negative, pole. Thus, the two poles being immersed in water, the water will be split up

FIG. 11

into its elements; oxygen collecting at the positive, hydrogen at the negative, pole. When a salt, as iodide of potassium, is decomposed, the acid element, iodine, is set free at the positive, the alkaline element, potassium, at the negative,

pole. When living tissues are acted on, an acid dry eschar forms under the positive, an alkaline moist slough under the negative, electrode.

FARADISM.

By "faradic" should always be understood the "induced" electrical current.

For all practical purposes the galvanic or primary and the induced or secondary currents are all that need be considered, as space will not allow a full discussion of the various "extra" currents, and any brief mention of them would only confuse the student.

When a galvanic current passes through one of two parallel conductors there appears in the other a current of electricity also, flowing, however, in an *opposite* direction when the primary galvanic current is made, and in the same direction when it is broken.

If these conductors, instead of being simple straight, parallel wires, be coils of insulated wire one within the other, an electrical current in one will still induce a current in the other. The

inner is generally the primary coil, and consists of a very few turns of a large insulated wire. This is constructed to offer as little resistance as possible to the generating current. The strength of the induced current depends considerably on the comparative length of the secondary coil, being proportionate to the total number of turns in the first coil, multiplied by the total number of turns in the second.

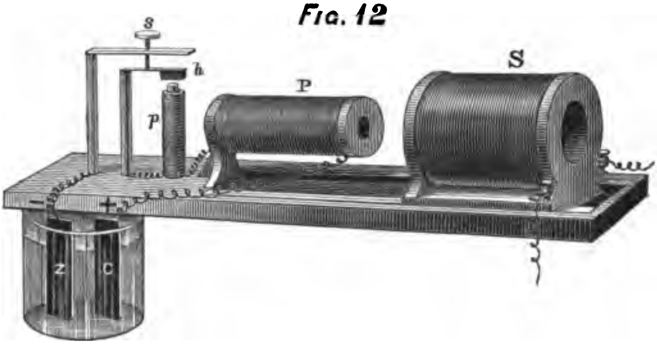
To encircle the primary coil as many times as possible with wire of great fineness is the aim of the secondary coil. The secondary coil has no contact whatsoever with the primary.

As a galvanic current induces electricity in a neighboring wire so does a magnet. If this magnet be not permanent but temporary, the electrical current flows one way when the magnet is made, the other when it is unmade.

Again, a galvanic current while passing through a wire about a piece of steel or soft iron makes of it a magnet, permanent in the case of the steel, temporary in the iron. Upon these facts depends the production of the faradic or secondary current, by means of a mechanism easily described with the help of the accompanying cut (fig. 12).

The current starting from +, the positive pole of a single galvanic cell, passes through the primary coil *P*, then through a small coil, *p*, which surrounds a core of soft iron, then ascends the

FIG. 12



post 1 to the spring hammer *h*, through the screw *s*, the horizontal arm, and post 2, back to the negative pole—making in this way a complete metallic circuit.

As soon, now, as the current enters the coil *p*, it makes the contained soft iron a magnet, which immediately attracts to itself the iron head of the spring hammer *h*. This pulls the spring hammer away from the screw *s*, and the circuit is broken. The instant the circuit is broken and the current stops, the core of soft

iron in the coil *p* ceases to be a magnet and lets go the iron armature on the end of the spring *h*, which by its elasticity flies back against the screw, thus again completing the circuit, when the same process is repeated, in most batteries, with sufficient rapidity to produce a musical sound by the vibration of the hammer.

If now over, but not touching, the primary coil, we slip a secondary coil of fine insulated wire, we will find a current of electricity generated in it, which, instead of having a definite direction, flows one way when the primary current is made, the opposite way when the primary current is broken. The current from the secondary coil differs in no way from the primary galvanic current, except in the fact that its direction is so rapidly reversed it has no true polarity.

If when the primary current is *made*, pole *a* is positive and pole *b* negative; when broken, *a* will become negative and *b* positive. Thus, if the primary current be interrupted two hundred times a second, two hundred times in each second the direction of the current changes, and neither *a* nor *b* is positive or

negative long enough to produce polar effects.

If now a core of soft iron is placed inside the primary coil *p*, it is made a magnet each time the primary circuit is completed, and is demagnetized each time the primary circuit is broken.

This has an effect on the primary coil which may be neglected, but, as we have seen that a magnet can also induce an electrical current in a neighboring coil, it also induces a to-and-fro current in the secondary coil, which augments that excited by the primary.

The cell supplying the current should be one of high electro-motive force and slight internal resistance, a cell which works well and lasts long when short-circuited. A single fluid, modified Smee cell,[1] is, all things considered, as good as any—cheap, easily cleaned and repaired, of low resistance, high electro-motive force, and adapted to a short circuit. A simple contrivance will enable the zinc to be immersed in or raised from the fluid as desired. To give the vibrating spring more elasticity, it should be of steel, with a piece of platinum soldered

[1] Zinc-carbon elements, bichromate of potash, sulphuric acid, and water fluid.

on its upper surface where the screw impinges, to prevent oxidization and poor conduction at that point. The primary coil should consist of a few turns of a large, well-insulated wire. The core of soft iron, also insulated, may be a solid rod or a bundle of wires, but in any case should be easily removable. The secondary coil should be of fine insulated wire, with as many turns as consistent with economy of space. It should be entirely disconnected from the primary coil, and should be capable of being gradually slid over or removed from the primary coil.

In only that portion of the secondary coil which overlaps the primary is a strong current generated; hence, if the secondary coil be movable, a fine graduation of the current can be made; this can also be done by the introduction or removal of the core of soft iron, which by its presence greatly intensifies the strength of the secondary current.

In some batteries, different strengths are attained by tapping the secondary coil at different points, but this admits only of coarse graduation of the current. In other batteries, a conducting,

hollow cylinder is introduced between the two coils, which lessens or even annihilates the inducing power of the primary coil. By a withdrawal of this cylinder more or less of the primary is allowed to act on the secondary coil. Mobility of the core of iron and of the secondary coil affords the best and most accurate means of graduating the current, and should always be insisted on.

Do not combine a faradic and galvanic battery in the same case.

The faradic has physical effects similar to the galvanic current, but it does not produce the osmosis, nor has it the electrolytic power of galvanism.

Moistened litmus paper will show neither an acid nor alkaline reaction at the poles of a secondary coil, because the acid set free one instant at a pole is, the very next instant, neutralized by the alkali set free at the same pole.

Because of this want of electrolytic power, the faradic fails to destroy living tissues, as does the galvanic current.

PHYSIOLOGICAL EFFECTS OF GALVANISM.

If well-moistened electrodes be attached to

the poles of a battery and applied to equally sensitive regions of the body, the first effect of turning on a strong current will be a burning, pricking sensation, more marked at the negative pole. This soon becomes an intolerable pain; the skin, under both electrodes, becomes very hyperæmic; minute blebs form under the negative electrode, which gradually coalesce and well-marked vesication ensues. The tissues between the electrodes are the seat of no visible alteration. So much for the gross effects of the uninterrupted galvanic current—simply an electrolysis of the tissues at the poles. If, during this experiment, the current be suddenly made or broken, severe pain is experienced, and a violent movement will take place. This is because a making or a breaking of the galvanic current suddenly excites into physiological action both nerve and muscle.

If a motor nerve be thus excited, contraction of the muscles supplied by it, will result; excitation of a sensory nerve will cause pain; while if a mixed nerve be aroused, both pain and muscular contraction will ensue. The nerves of special sense are functionally dis-

turbed, and, when a galvanic circuit is made or broken about the head, a metallic taste, and perhaps flashes of light, a queer smell, and a roaring in the ears, occur from excitation of the gustatory, optic, olfactory, and auditory nerves respectively.

With one electrode on an indifferent point,[1] as the sternum, and the other, with an interrupting handle, on a nerve-trunk, as the musculo-spiral, we find, experimentally, that extension of the wrist will first take place on making the circuit with the negative on the nerve. The next contraction will occur when, after turning on more cells, the circuit is opened, the positive being on the nerve. By the addition of a few cells more, contraction appears on closing the circuit, the positive being on the nerve.

Thus, *Ca* representing the cathode (or negative pole), *An* the anode (or positive), *c* closure,

[1] The "indifferent point," so called, should be some part in the median line of the body, preferably where sensibility is not acute and where there is no muscular tissue to excite. The sternum is the best spot, and should always be used for the indifferent electrode in scientifically conducted electrical examinations and applications. In this way we get pure polar effects at the other electrode, which is almost impossible if both electrodes be on one side of the body or on the same extremity.

o opening, *C* contraction, we would have as a formula of normal nerve reactions to galvanism:

$$CacC > AnoC > AncC > CaoC;$$

the last not being obtainable, as it necessitates the employment of an unbearably painful current.

When one electrode is on an indifferent point, and the other on the motor[1] point of a muscle, we find that contraction is produced with fewer cells, when the anode is on the muscle, at the closing than at the opening of the circuit. Hence for normal muscle reactions we have the formula :

$$CacC > AncC > AnoC > CaoC;$$

the latter being never seen.

The contractions thus produces are quick and of momentary duration,[1] unless the current be *very* strong, or the nerve or muscle be over-excited or fatigued, when they may be rather slow and prolonged—*i. e.*, tetanized.

[1] By carefully examining muscles there is found in all a small area where contraction is produced by a comparatively mild and painless current. This is called the *motor point* of a muscle, and is located over the point of entrance of its motor nerve.

PHYSIOLOGICAL EFFECTS OF FARADISM.

The induced current produces a tingling sensation which, if the current be strong, finally merges into a numbness. When applied by a dry metallic electrode it is very painful, and if carried to the body by means of a single metallic wire, it makes one of the most painful applications known.

Passed through healthy nerve or muscle it causes quick contractions, which are continuous, lasting until the current is broken—*i. e.*, tetanic.

REACTION OF DEGENERATION.

These normal physiological effects are altered in various ways in different pathological conditions of nerve and muscle.

When the continuity of a nerve is broken, pathological processes follow which are beyond the scope of this work to describe in detail, but which consist chiefly in a granular breaking down, and nuclear proliferation of the myelin sheath of the nerve-fibre, and a resulting baring and granular degeneration of the axis-cylinder; the processes terminating in connective-tissue

proliferation and ultimate cirrhosis; the muscles supplied by the severed nerve becoming granular, fatty, and finally cirrhosed.

The moment pathological changes begin, reactions of both nerve and muscles are altered.

When the lesion is destructive and irremediable, there is a gradual failure of galvanic and faradic excitability of the nerve, ending in an entire disappearance of the same in a few days.

An experimental demonstration of this gradual death of a severed nerve is afforded by the accompanying plate.

In the first place, normal nerve and muscle reactions were taken in healthy frogs as follows: By means of a double interrupter, the circuit carrying electricity to the frog is made and broken at the same time as the circuit of the chronograph, hence the moment the electricity reaches the muscle it also reaches the chronograph and breaks the line.

Having broken up the brain and spinal cord of the frog, to stop voluntary and reflex movements, the sciatic is exposed, the tendo Achillis is cut and fastened to the myograph needle, and the frog is securely pinned to the cork

stage, with one electrode under the nerve and the other in some indifferent point, as the small of the back. We take the tracings produced by the cathode (neg.) closure contraction, cacc, and the anode (pos.) opening or closure contraction, anoc or ancc, excited by a small Grenet cell, and afterward the reaction to the secondary current of an induction apparatus. The same process is repeated with the muscle.

The sciatics of several frogs were cut and the animals were kept in a *very* warm room, so that nerve degeneration would not be retarded for perhaps weeks, as it sometimes is in frogs, especially in the winter.

Each day a frog was killed, pithed, and put through the same routine treatment as the healthy ones had been. After the electrical examination, a microscopic study of the injured nerves and muscles was also made.

The changes in the nerve reactions following section were as follows: Forty-eight hours after section decided changes had taken place; cacc had diminished two thirds, anoc and cc were about the same, and faradic reaction was

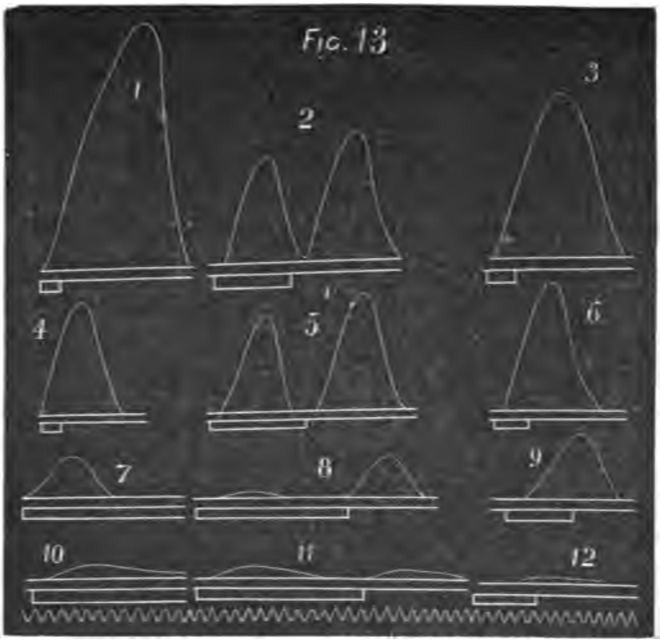


Fig. 13.—Myograms from excitation of the nerve in the frog.

Fig. 1.—Normal cacc; fig. 2, normal ancc and oc; fig. 3, normal fc, with secondary coil 7 c. distant.[1]

Fig. 4.—Cacc; fig. 5 ancc and anoc; fig. 6 fc, on second day of section, with secondary coil 7 c. distant.

Fig. 7.—Cacc: fig. 8 ancc and anoc; fig. 9 fc, on third day of section, with secondary coil 7 c. distant.

Fig. 10.—Cacc; fig. 11 ancc and anoc; fig. 12 fc, on fourth day of section, with secondary coil 7 c. distant.

The line on which the curves stand is called the base line, and is made by the myograph needle when at rest. The straight line below and parallel to this is made by the chronograph needle at rest, and the deviations from it denote the duration of the passage of the electric current. The wavy line underneath is made by a tuning-fork vibrating one hundred times to the second.

[1] A current just perceptible to the tongue.

diminished about one third. On the third day cacc = $\frac{1}{6}$, anoc = $\frac{1}{4}$, ancc just perceptible, and fc $\frac{1}{3}$ its normal amplitude. On the fourth day cacc was diminished to $\frac{1}{18}$th, slow and tetanized; anoc was diminished to $\frac{1}{12}$th; ancc the same size, and both very slow and tetanized; fc about $\frac{1}{16}$th, retarded, slow, and tetanized. On the fifth day of section no nerve reaction to galvanism or faradism could be detected.

The Wallerian degeneration began to be very distinctly discoverable, on microscopic examination of the nerves, on the third day, increased each day, and on the fifth, and afterward, was complete, the nerves being one mass of broken myeline matter, nuclei, granular detritus, and naked axis-cylinders. The nerve died early in these frogs because of the warm temperature in which they were kept. In man the nerve ceases to respond, if cut or badly bruised, on the seventh to the fourteenth day.

In man when the injury is not destructive or irreparable such rapid and complete loss of electro-excitability does not occur. Faradization of the injured nerve seldom causes muscular contraction, while that produced by galvanization is

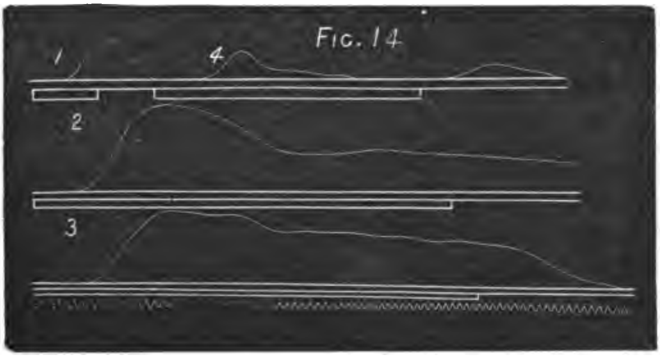
peculiar. The contraction caused by the anode closure becomes greater than that of the anode opening, and, finally, greater than the cathodal closure contraction. This constitutes "degeneration reaction," of which the formula is reversed ancc > cacc > anoc > caoc; the caoc sometimes appearing before the anoc.

The commencement and progress of these degenerative changes can be seen in the accompanying myograms taken from a case of facial paralysis.[1]

In Bell's palsy of the face we have a disease very closely resembling nerve section, a resemblance which, in incurable cases, amounts to an identity as regards pathological changes and external phenomena. It matters not how muscles are severed from their centres, whether by neuroma, neuritis, compression, contusion, or section, an identical result will follow an irreparable injury, viz.: degeneration of the nerve and muscular atrophy. For this reason the accompanying case of Bell's palsy is a good one to place alongside of frogs whose nerves were cut.

[1] This should be compared with the healthy myographic curves on the folded leaf which can be turned out from the back cover of the book.

The mode of recording facial muscular movements was by means of connecting the cheek, in the neighborhood of the angle of the mouth, with the myograph, by means of a piece of isinglass plaster, stuck to the skin, from which a thread was carried to the lever. Then the head was placed so that, the thread being taut, any slight facial movement was recorded on the smoked paper.



HUMAN MYOGRAMS REDUCED ONE THIRD. CASE OF BELL'S PALSY.

Fig. 1. Cacc 32 cells; fig. 4, ancc and anoc 32 cells, nerve excitation, fourteenth day.

Fig. 2. Cacc 40 cells; fig. 3, ancc 35 cells, nerve excitation, thirty-first day.

The first examination was made in the second week of the paralysis. The formula then stood:

Nerve, cac C > ano C. No fc.

On the thirty-first day a second examination was made, when degeneration reaction was much more marked. The nerve was still excitable to galvanism however. The formula stood:

Nerve, anc C 35 cells about = cac C 40 cells. No fc.

thus showing a very well-marked degeneration reaction.

Retarded and tetanoid contractions also characterize degeneration reaction, but more will be said of this later.

The electrical reactions of degenerating muscles in frogs were studied as follows. Each day, after excising the sciatics, a new frog was killed, pithed, and tested.

First, a curve was produced by cacc, then by ancc, then by an induced current from a secondary coil. Forty-eight hours after section there was already diminished amplitude of muscular movements, shown by lower curves, and already ancc > cacc, while there was a commencement of tetanization in the anode curve, *i. e.*, the down-stroke was slanting and prolonged (fig. 15, curve 24). On the third day ancc was > cacc,

while fc was very slight indeed; cacc also showed tetanization, the curve being rounded, and prolonged long after the electric stimulus was withdrawn. The latent period[1] was already lengthened (the normal duration of the latent period being about $\frac{1}{100}$ second). In certain pathological states[2] this period is much prolonged, and the time elapsing between the entrance of the electricity into the muscle and its contraction, is visible to the eye, but much better by aid of a myogram. This retardation is particularly marked in muscles showing degeneration reaction.

On the fourth day tetanization was still more complete, the muscle not relaxing at all during the continuance of the current, and not even till several hundredths of a second after the opening of the circuit.

On the sixth day cacc is smaller, and there appears also a small caoc; ancc is larger and very tetanic.

On the seventh day cacc is small ($\frac{1}{6}$ the ampli-

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[1] The latent period is the time elapsing from the excitation of the muscle to its contraction.

[2] Mendelssohn: Sur le temp des muscles. Physiol. experiment. (Marey), Paris, 1880.

tude of the normal) and tetanic; ancc is $2\frac{1}{2}$ times > cacc.

On the sixteenth day, fig. 15, curves 7, 14, 15, there is hardly a trace of cacc with one cell, while five cells produce a slow contraction retarded $\frac{5}{100}$ second, while the single cell still produced a large and tetanized ancc, *i. e.*, ancc was ten times > cacc. Fc was only obtained by bringing the secondary in contact with the primary coil, producing a current which threw the frog into general tetanus, the current thus produced being almost painful to the operator's hand.

FIGURE 15.—**Myograms produced by direct stimulation of frog's muscles before and after section of the sciatic nerves.**

FIG. 1.—Normal cacc 1 cell; fig. 26, normal ancc 1 cell; fig. 27, fc, with secondary coil 4. c. distant.

FIG. 2.—2d day of section cacc, 1 cell; fig. 24 ancc, 1 cell; fig. 25 fc, with secondary coil 4. c. distant

FIG. 3.—3d day of section cacc, 1 cell; fig. 22 ancc, 1 cell; fig. 23 fc, with secondary coil 4. c. distant.

FIG. 4.—4th day of section cacc, 1 cell; fig. 20 ancc, 1 cell: fig. 21 fc, with secondary coil 4. c. distant.

FIG. 5.—5th day of section cacc, 1 cell; fig. 18 ancc, 1 cell; fig. 19 fc, with secondary coil 4 c. distant.

FIG. 6.—7th day of section cacc, 1 cell; fig. 16 ancc, 1 cell; fig. 17 fc, with secondary coil 4. c. distant.

FIG. 7.—16th day of section cacc, 5 cells; fig. 14 ancc, 1 cell; fig. 15 fc, with secondary coil in contact.

FIG. 8.—20th day of section cacc, 1 cell; fig. 12 ancc, 1 cell; fig. 13 fc, with secondary coil in contact.

FIG. 9.—37th day of section cacc, 5 cells; fig. 10 ancc, 1 cell; fig. 11 fc, with secondary coil in contact.

FIG. 28.—44th day of section cacc, 5 cells; fig. 29 ancc. 1 cell; fig. 30 fc, with secondary coil in contact.

Line at bottom marking $\frac{1}{100}$ths of a second.

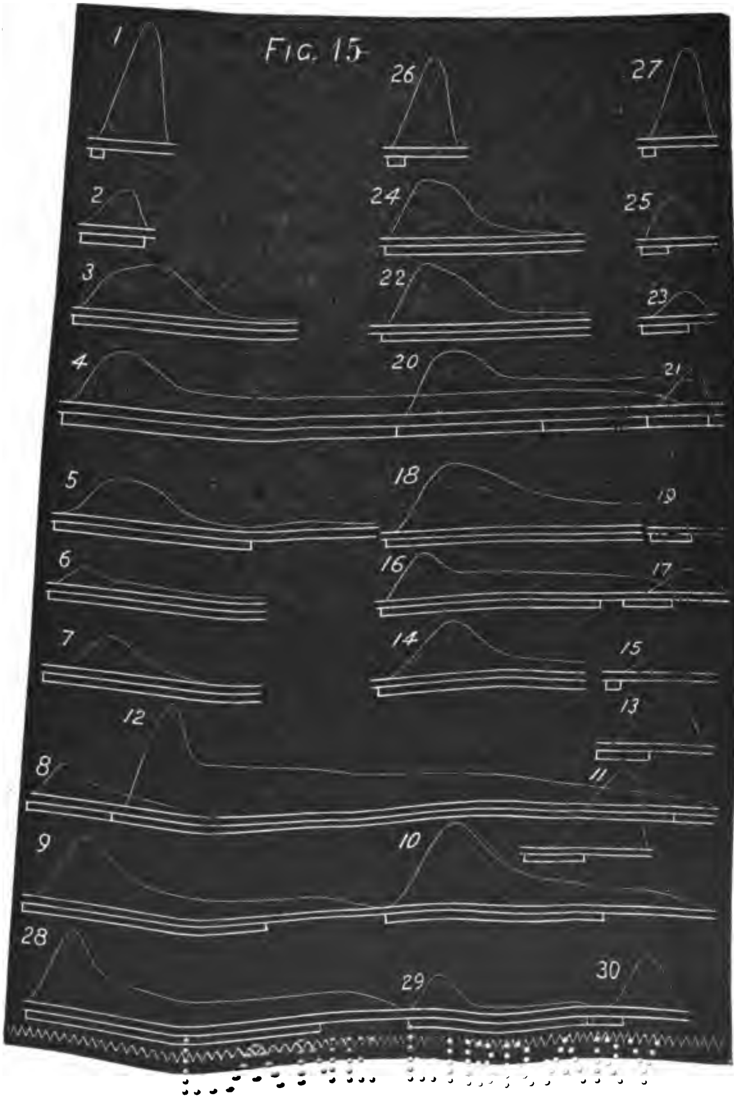
FIG. 15
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On the twentieth day there was a small cacc (fig. 15, curve 8) to one cell, while the anode of the same cell excited an immense tetanized curve. A fair fc, which was retarded, was produced by the secondary coil at contact.

On the thirty-seventh day the myographic curves presented peculiarities which, as examples to follow will show, must be considered as pathognomonic of the degeneration of nerves. From the first it has been shown that the down-stroke was getting more and more slanting and slow to reach the base line; *i. e.*, the muscle was slow to relax, and partly tetanized. Now, on the thirty-seventh day, and later, tetanization becomes complete; *i. e.*, so long as the galvanic current is allowed to pass through the muscle, it will not relax, but as soon as the circuit is broken, a slow relaxation takes place. This is shown in curves 9, 10, and 28, where we have a sloping up-stroke, a rounded top, a sloping down-stroke to a certain point where it remains stationary until, when the circuit is broken, it gradually falls to the base line.

This series of myograms shows graphically the progressive changes, quantitative and quali-

tative, which an irreparable injury to a motor nerve produces in its muscles. First, the retarded, tetanized, and gradually vanishing cacc; secondly, the retention of ancc, which, however, is also retarded and tetanized; thirdly, the preponderance of ancc over cacc; and lastly, the rapid failure of faradic contractility;—the latter seemingly large contractions to faradism being the results of the application of a stimulus ten or more times the strength of the current first used. The reason that fc is retained at all is because the electrode comes in direct contact with the muscle, the same thing occurring in man if the muscle be punctured.

The only histological change noticed in the muscles of the frogs experimented on, was a granular, disintegrated condition of the intramuscular nerves.

Such are the phenomena of true degeneration reaction—only seen in cases of destructive lesions of the cord, the motor cells of the cord, polio-myelitis anterior, and by destructive lesions of peripheral nerves.

The electrical reactions present in other pathological conditions will be mentioned with the treatment of such conditions.

GENERAL DIRECTIONS FOR ELECTRO-DIAGNOSIS.

In making an electric examination the faradic current is generally used first. A large flat electrode, connected with one end of the secondary coil, should be placed on an indifferent point. A second electrode, with an interrupting handle, is placed over the nerve to be examined, and enough of the secondary coil is put in requisition to cause contraction of muscles supplied by the nerve, or till an unbearably painful current be reached. The length of the secondary coil should be noted and compared with the length needed to excite the corresponding nerve on the opposite side, if healthy, or some other healthy nerve. Putting the interrupting electrode on the motor point of the muscle its reactions are taken in the same way.

Then connect the rheophores with the galvanic battery and, with the electrodes left in situ, ascertain the current strength necessary to obtain the various opening and closure contractions, and compare them with similar tests on healthy tissues. The results of such examinations should be recorded for future reference.

To make the examinations more accurate

every effort should be exerted to make the details of examinations alike, particularly as regards the strength of current employed as denoted by galvanometric readings.

As an example let us suppose a case. A patient presents himself with paralysis of the extensors of the wrist and hand of a month's standing. Let us see how much light a careful electrical examination of the part will throw on the case.

Rheophores, attached to the termini of a secondary coil, are connected, one with a large flat electrode placed on the patient's sternum, the other with an electrode, with an interrupting handle, held over the musculo-spiral nerve as it winds around the humerus below the insertion of the deltoid.

The current is now started and increased until contractions take place in the tributary muscles, or the current becomes unbearably painful. If normal contractions occur the subject is malingering, or the paralysis may be of an hysterical or cerebral origin. If exaggerated reactions occur, the paralysis may be hysterical, but is more likely dependant on a cerebral lesion.

If the reactions are much less marked than normal, but still present, the paralysis may be due to a non-destructive spinal or peripheral nerve lesion. If no bearable faradic current will excite the nerve, the paralysis is caused by a destructive lesion of the motor spinal cells, which innervate the musculo-spiral nerve, or by a destructive peripheral lesion in the nerve itself.

Putting now the small electrode on the motor point of one of the paralyzed extensors, if normal contractions ensue the paralysis is probably feigned, but may be hysterical or cerebral. If the response is exaggerated the paralysis may be hysterical but is presumably cerebral. If the reaction occurs slowly and feebly, the paralysis is, perhaps, due to a depressing but not destructive lesion of the motor cells of the spinal cord or the musculo-spiral nerve. If no contraction can be produced by direct faradization of the paralyzed muscles, there exists a destructive lesion of the motor cells in the spinal cord or a destructive lesion of the peripheral nerve.

The deductions from a galvanic are similar to those from a faradic examination. The electrodes are placed as before. An increasing

number of cells is turned on until, the current being made and broken by pressing and letting go the spring of the interrupting handle, contractions occur in the extensors.

If the usual current strength, applied to the nerve, causes the muscles to react in the normal way—*i. e.*, to give the normal formula : cacc > anoc > ancc, you may assume at once that the paralysis is probably feigned, but may be hysterical and cerebral. If the nerve responds in a normal way but to a weaker current than usual the paralysis may be feigned, but probably is hysterical or cerebral. In this case the galvanic reactions are said to be quantitatively [1] altered.

During the galvanic examination it may be found that the nerve responds as quickly to anodal as to cathodal excitation. The normal formula will be disturbed, and we will have,

$$cac\ C = ano\ C > anc\ C, \text{ or}$$
$$ano\ C \text{ slightly} > cac\ C > anc\ C.$$

This, will, of course, indicate that slight degenerative changes have invaded the nerve and

[1] By quantitative alteration of reaction is meant an abnormal excitability or insensibility to the current ; the normal formula being retained.

that the paralysis depends on a depressing but non-destructive lesion of the motor cells of the spinal cord or peripheral nerve.

If no galvanic excitation causes a response in the nerve, the paralysis is due to a destructive lesion of the motor cells of the spinal cord or a breach of continuity of the peripheral fibres.

In direct muscular excitation, if the reactions are in every way normal the paralysis must be feigned, hysterical, or cerebral. If hysterical or cerebral they may be exaggerated but not qualitatively altered.[1]

Any qualitative alteration in the reaction of muscles indicates degenerative changes, and points to a lesion of the motor cells of the spinal cord or of the nerve, destructive in proportion to the change in the formula. Thus, if the cathodal and anodal response are about alike,

$$cac\ C = anc\ C > ano\ C,$$

it is pretty safe to say that, considering the duration of the paralysis, the lesion is not destructive. But if anodal occurs quicker and is stronger than cathodal contraction,

[1] By qualitative alteration is meant a perversion of the normal formula.

$$anc\ C > cac\ C > ano\ C, \text{ or}$$
$$anc\ C > cac\ C > cao\ C,$$

both being tetanoid, then the paralysis must be due to a destructive lesion in the spinal or peripheral motor tract.

The above remarks apply to a localized paralysis, about which nothing is known except that it is of one month's standing. Of course there are *never* cases in which one has to rely entirely on electrical reactions, but much assistance is derived in making the differential diagnosis from physical signs and clinical data.

For instance, in a case like the above, either a poliomyelitis anterior in the cervical cord, a poisoning by lead, or an injury to the nerve filaments forming the musculo-spiral nerve might be the cause of the paralysis, and, in all, the electrical reactions might be exactly the same, but other facts make the differential diagnosis easy, as the accompanying table may show.

Paralysis from	Peripheral lesion.	Degeneration reaction.	Muscular atrophy.	Disturbances of sensibility, as anæsthesia, analgesia, hyperæsthesia, causalgia, pain, etc.	Trophic changes very marked.	Generally unilateral.	All the muscles.	Onset sudden, preceded by injury.
	Lead.	"	"	O	Very slight.	Generally bilateral.	Supinator longus exempt.	Onset slow, preceded by history of lead.
	Poliomyelitis anterior.	"	"	O	Very slight.	Generally bilateral.	All the muscles.	Onset sudden, following constitutional disturbances or fever.

If a localized paralysis be only of short standing, say a day, the electrical examination will help very little, as the reactions would be about the same were the paralysis of cerebral, spinal, or peripheral origin, but in this case the history and symptoms of the case would make the diagnosis easy.

In some paralyses of very long standing the faradic and galvanic applications, or even electro-puncture, cause no contractions. In these cases there either never was any muscular tissue (some congenital paralyses) or the muscular

fibres have undergone complete fatty or connective-tissue degeneration.

The results of electrical examinations should be systematically recorded in some way, the exact form being unimportant. The following form is simple and sufficient.

James Brown, — June 11, 1883.

Left facial paralysis; mild case; two weeks' standing; contractions slow and tetanoid.

NERVE REACTIONS.

Left Nerve.		Right Nerve.
20 cells.	cacc.	20 cells.
15 "	anoc.	25 "
25 "	ancc.	30 "
No c.	caoc.	No c.
No c.	f.	3 cent.[1]

MUSCLE REACTIONS.

Left orbicularis palpebrarum.		Right orbicularis palpebrarum.
15 cells.	cacc.	20 cells.
10 "	ancc.	30 "
20 "	anoc.	40 "
20 "	caoc.	No c.
No c.	f.	3 cent.[1]

The formulæ in this case could then be written:

Nerve, $ano\ C > cac\ C > anc\ C$; *no fc.*

Muscle, $anc\ C > cac\ C > ano\ C = cao\ C$; *no fc.*

[1] 3 cent. means that three centimeters of the secondary coil overlapped the primary.

Ordinary GALVANIC APPLICATIONS are continuous or interrupted, stabile or labile.

A continuous or stabile application is made by applying to the desired points the electrodes, connect them with the battery, and then gradually turn on cells to give the desired strength of current. The electrodes remain stationary until, the application being over and the current being turned off, they can be removed. Some authorities lay stress upon the *direction* of a continuous current. It is said to be "ascending" when the positive pole is on a peripheral part and the current flows toward the nervous centre; "descending" when the positive pole is centrally placed and the current flows toward the negative pole, which is applied to a peripheral part.

More physiological, and hence undoubtedly more therapeutical, effect centres about the poles, therefore more attention should be given to the location of the electrodes than to the direction of the currents.

Various contrivances are employed which mechanically interrupt the current at regular intervals, but an interrupting handle answers all ordinary purposes.

A labile application is really a slowly interrupted galvanic current, but it is more. It consists, having one electrode in an indifferent point, in slowly stroking the skin over the diseased part with the other, which is covered with a wet sponge. In this way the contraction of an entire muscle can be secured when an excitation at its motor point causes contraction only of the muscular substance in its immediate neighborhood.

FARADIC APPLICATIONS also are stabile and labile; but a more common mode of faradizing is by "dabbing" different parts, especially the motor points of muscles, with one electrode, the other remaining stationary. In all applications but one, of both currents, the electrodes should be kept wet with warm plain water. In one faradic application, the surface to be acted on is kept dry, and the current is applied by means of a wire brush, the other extremity of the coil being connected with a well-wetted electrode which is held on an indifferent point.

THERAPEUTIC APPLICATIONS OF ELECTRICITY.

THE limits of this book forbid the introduc-

tion of any controversial matter or the narration of unproven theories ; hence, under "treatment" will be discussed *only* therapeutic applications of electricity which the writer himself has found of undoubted utility in his practice—methods of application being given with as much detail as the space will permit.

In attempting to portray the chief therapeutic applications of electricity, an endeavor will be made to suggest different pathological conditions, *not* symptoms or names of diseases, as indications for treatment. And we may premise these remarks by saying that, in our opinion, *by far the most brilliant curative results brought about by electricity depend wholly on its power to excite muscular contraction.* Such being the case, most space and minuteness of detail will be allotted to those diseases wherein this constitutes the most rational and nearly the only therapeutic procedure.

MUSCULAR SYSTEM.

Congenital deformities, chief among which is club-foot, are best remedied when, in addition to the operative procedures and mechanical ap-

pliances of the skilled orthopœdist, systematic electrical treatment is persisted in for months. After the malposition is overcome, the undeveloped or weak muscular groups should be gently faradized, if the secondary current excites contractions, or galvanized if it does not. The application in each event should be localized and labile, relaxing the diseased muscles to their fullest extent by a forced position of the limb and then slowly stroking the skin over the group with a soft large sponge electrode well wetted, using the faradic or the positive or negative pole of the galvanic, whichever produces the best contractions with the minimum current and the least pain. Applications of five to ten minutes' duration of a current strong enough to excite moderate contractions should be made at least tri-weekly for months.

Unfortunately electricity cannot create muscular tissue where rudiments or degenerated remains of it do not exist. Hence, in those cases where muscles or groups of muscles are congenitally absent, electricity will do no good, except, perhaps, to develop other muscles which may be made to act somewhat as substitutes for missing muscles.

When, however, an early developed deformity depends on a rudimentary condition of muscles or a degenerated condition dependent on intrauterine or early infantile injury or disease, electrical treatment may be of inestimable value.

Muscles, like other organs, require a certain amount of functional activity for the proper maintenance of their healthy structure. Functional activity of a muscle is occasional vigorous contraction. When muscles remain idle for some weeks, slight degenerative changes set in, which, if the disuse last long enough, go on to the production of some fatty degeneration, absorption, and consequent atrophy (wasting) and paresis (weakness). Such muscular changes are seen after long detention of an extremity on a splint for fractures, operative wounds, various inflammatory troubles, and rheumatism; after long immobility of a part because of the presence of pain; and in the course of chronic arthritic or synovial disease. Those acquainted with the use of electricity have noticed that the electrical reactions in these cases were slow, but only quantitatively not qualitatively changed, *i. e.*, the normal formula is retained; faradic ex-

citability of nerve and muscle is retained, but lessened. All contractions are retarded and slow, showing a tendency toward tetanization.

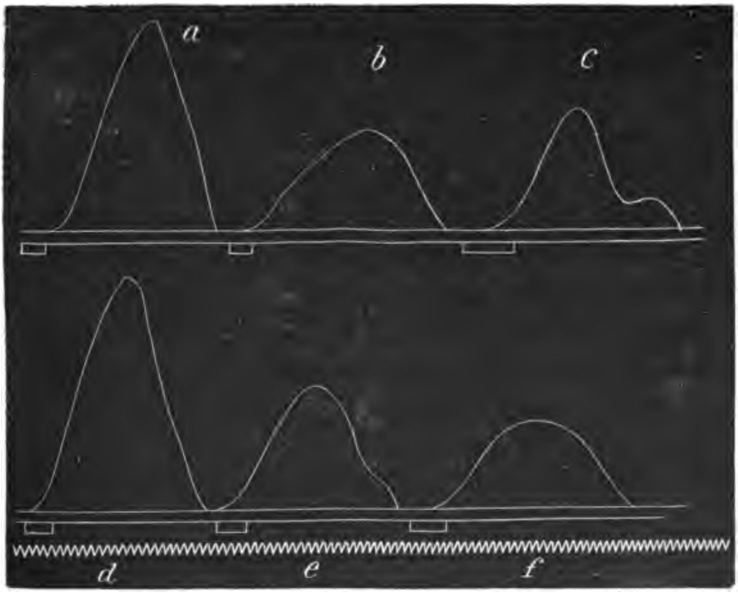

FIG. 16.—Myograms from case of long disuse of hand from rheumatism and splint; reduced one third; contractions of abductor indicis.

a — cacc (nerve current), 27 cells. b — anoc (nerve current), 42 cells. c — fc (nerve current), with 2.5 cent. secondary coil. d — cacc (muscle current), 42 cells. e — ancc (muscle current), 47 cells. f — bc, with 2 cent. of secondary coil.

Changes of reaction which are insignificant to the naked eye are made very manifest when amplified and made graphic by myograms.

Such cases are best treated, in conjunction with passive movements and friction, by mild, labile faradic, unless labile galvanic applications produce better contractions and are pleasanter. Care, of course, must be taken not to confuse these with cases where real injury is done nerves, but in that case, of course, the reaction of degeneration is seen.

INJURIES OF PERIPHERAL NERVES, in proportion to their severity, induce pathological changes principally in the nervous tissue peripheral to the injury and in the muscles they supply. Three classes of peripheral-nerve injury are seen. In one, the light form, only small injury is done the nerve, connection with the nutrient centre is not severed, and recovery rapidly supervenes. In such cases it rarely happens that the nerve completely loses its electro-excitability, but the reactions are quantitatively, perhaps qualitatively altered. Such is the condition in the light case of Bell's palsy alluded to on page 44, where the myograms from nerve excitation were given. In these light cases, of a few weeks' duration, decided changes in muscular contractility occur, faradic

contractility being lost and the formula for galvanic reactions being generally reversed.

This condition of things is better demonstrated than described, as the accompanying myograms from the same case of Bell's palsy show.

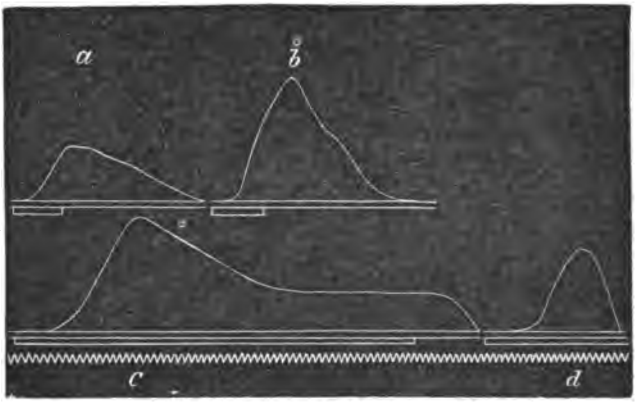

Fig. 17. Myograms, reduced one half, from direct muscular excitation in a mild case of Bell's palsy.
a = cacc, 25 cells; b = ancc, 25 cells. 14th day of the disease, ancc > cacc.
c = cacc, 20 cells; d = ancc, 12 cells. 31st day, ancc very much > cacc.

Here again we see examples of what I consider to be myograms characteristic of degenerating muscles already spoken of on page 50. Curve *c* in fig. 17 is typical: delayed contraction (long latent period); gradual contraction (a sloping up-stroke); and a tetanic contraction

(a gradual descent and a continuance of contraction till after the current is broken).

The treatment, in these mild cases of nerve-injury, besides passive movements, mild massage, and position, consists in labile galvanic applications, with the pole which produces the best contractions, generally the anode, with a current just sufficient to produce fair contractions. If possible, daily mild applications should be made till faradic contractility reappears, when the faradic current can be substituted, or both may be used separately until recovery takes place.

In these cases, where the nerve will respond to galvanism after the fourteenth day, and where, in nerve and muscle, ancc or oc is but little if any larger than cacc, the prognosis is good.

In the medium degree of nerve injury, complete solution of continuity of the nerve-fibres occurs, and there immediately ensues an anæsthesia and paralysis in its distribution, if it be a mixed nerve, followed by degenerative changes in the distal nerve and the muscle.

It matters not *how* this solution of continuity

is caused, whether by a contusion, compression, laceration, section, neoplasm, or inflammation, the result is the same—*i. e.*, a Wallerian degeneration in the peripheral nerve-fibres and a commencing fatty change in the muscles.

In these cases, by some obscure reparative process, the ends of the severed nerve-fibres reunite, continuity becomes re-established, and final restoration of healthy structure and function takes place. This ultimate recovery is sometimes very retarded. In these cases there are gradual failure and final loss of all electro-excitability of the nerve, a loss of farado-contractility in the muscles unless they be punctured, and a more or less altered galvanic reaction. It is upon the electrical examination, helped by the state of sensibility, etc., etc., that we principally rely in forming our prognosis in these cases. If, after some weeks, sensibility being not much impaired, we find that, to a muscle current, cacc > ancc or cacc = ancc, even if there be no fc, we conclude that perhaps the injury to the nerve may be after all not irreparable and that recovery may still supervene.

In the severer forms of injury to peripheral

nerves, as crushing, laceration, or excision of a segment, complete recovery rarely ensues; nerve and muscle both degenerating, as described on p. 43, the nerve finally becoming a cord of connective tissue, the muscle a mass of connective tissue and fat.

The nerve in these cases quickly loses all vitality, responding to neither current, but as long as any muscular tissue remains it responds to galvanism; the reaction, however, bring that of degeneration, ancc being very much > cacc, and no fc. being seen unless the muscle be punctured.

It is pretty safe, in any case where ancc is decidedly greater than cacc, to give an unfavorable prognosis.

The electrical treatment is the same in these cases of profound injury to nerves as in the milder cases. A caution to which too much prominence cannot be given is, that treatment should be persisted in for a very long time, regeneration of the nerve and ultimate recovery sometimes occurring after months have elapsed.

Watch the trophic changes of the skin; measure the part frequently to see whether the

atrophy be progressing; test the state of sensibility often; make frequent, thorough electrical examinations, in which, if a tendency to return to the normal formula be shown, or faradic contractility reappear, ultimate recovery may be assured.

The treatment of sequelæ of neuritis—*i.e.*, paralysis and atrophy—is the same as of other nerve injuries.

In many of the above-mentioned forms of peripheral-nerve injury or disease the pathological process, by implicating the sensory fibres, gives rise to pain, which, in some instances, is relieved by a labile or stabile galvanic application to the painful point.

SPINAL DISEASES.

I will premise my remarks on the electrical treatment of spinal affections by stating that electricity, applied externally, has very slight physiological action on the healthy cord, and hardly any undeniable therapeutic effect on it when diseased. The recorded results of physiological experiments are few and ambiguous. The results of electrical treatment directed to the cord itself are so delayed and various that only

the most vague empirical deductions can be drawn.

Far different is the case when electricity is applied to the muscles which, in these cases, are often secondarily diseased.

In destructive lesions of the cord, as contusion, compression, laceration, transverse myelitis, etc., electrical treatment is contra-indicated in the acute stage. The time for commencing and the kind of electrical applications vary according to the exact pathological condition present.

In general terms it may be stated that all we can expect from electricity is to keep the muscles healthy until repair of the spinal lesion has taken place.

After a DESTRUCTIVE LESION OF THE ENTIRE CORD to a certain level, as in injuries, large hemorrhages and areas of softening (myelitis), we have ensuing, in the portion of the body supplied by this part of the cord, the same train of symptoms and pathological changes which follow destructive lesions of peripheral nerves: anæsthesia and paralysis, trophic changes in the skin, and muscular atrophy. The electrical reaction is that of degeneration, and the electrical

treatment consists of labile galvanic applications to the paralyzed parts. The approach of repair, if it take place, in the diseased cord, will be heralded by a return of sensibility and power, the reappearance of faradic contractility, and a normal reaction to galvanism.

Electrical treatment should be persisted in for months in these cases in view of an unexpected repair of the spinal lesion.

The relaxed bladder and rectum in these cases are not amenable to electrical treatment.

In POLYOMYELITIS ANTERIOR in adults and children, sudden destruction of the motor cells of the anterior horns of the spinal cord, there results a paralysis and atrophy similar to that caused by section of peripheral nerves, except it is unaccompanied by sensory disturbances. Neither are the bladder and rectum affected. The amount of the atrophy depends on the magnitude and duration of the lesion. In typical cases, nerve and muscle undergo degeneration, and degeneration reaction to galvanism is present as long as any muscular tissue remains.

The electrical treatment of these cases consists of labile galvanic applications to the paralyzed

parts, supplemented in many cases by orthopedic appliances to remedy deformity or support paralyzed extremities. Recovery is often delayed, and treatment should be persisted in for months.

In cases where degeneration and slow destruction of the motor cells of the spinal cord causes PROGRESSIVE MUSCULAR ATROPHY, electrical treatment is of no avail.

There are some cases where the disease appears to be restricted to a small group of cells, and a limited, very localized muscular atrophy ensues. Such a process is very apt to invade the cells innervating the muscles of the thenar and hypothenar eminences, beyond which the atrophy does not spread. These cases are amenable to labile galvanic treatment in about the same proportion as are cases of polio-myelitis anterior.

In the paralyses following febrile disorders, and where LEAD, ARSENIC, or other MINERAL or DIPHTHERITIC POISON injures the motor tract of the spinal cord, the nerves and muscles undergo, after a time, the same changes as in polio-myelitis anterior, and their electrical treatment is the

same. In lead paralysis, for instance, one electrode of a galvanic battery is placed on an indifferent point, while the paralyzed muscles are stroked with the other.

When the continuity of the cord is broken by an injury, neoplasm, hemorrhage, or softening, leaving a segment of the cord intact below the lesion, degenerative changes do not at once set in in the paralyzed parts which receive their innervation from the segment of the cord below the lesion, for this same region of the cord contains the trophic centres for the paralyzed muscles.

The loss of voluntary power in these parts necessitates prolonged inactivity, and finally, from disuse, a general progressive wasting sets in.

At a variable period of time after the solution of continuity occurs, a descending degeneration commences in the distal segment of the cord, manifested externally by the appearance of contractures which go on to the production of tremendous deformities in the paralyzed parts.

As to the electrical part of the treatment of these cases, as soon as the acute stage is over

the muscles may be kept healthy by daily or twice daily gently faradizing the paralyzed parts. In any case only a current strong enough to produce moderate muscular contractions should be used, and if there be signs of irritation, *i.e.*, much jerking of the limbs, or as soon as any indication of contracture sets in, all electrical treatment should be discarded. For the relief of the distressing condition of the bladder and rectum in these cases electricity avails little.

CEREBRAL DISEASES.

When the electrodes are applied to the head the amount of electricity which really penetrates the substance of the brain, and its effect on the brain if it does reach it, are matters of extreme uncertainty. The results of clinical experimentation are equally unsatisfactory. These and many other facts lead me to state it as my conviction that electricity, as ordinarily applied to the head, is devoid of any curative power over tangible cerebral lesions. How far it may sometimes prove potent in curing the minuter changes, upon which no doubt depend many of our so-called functional diseases, is hard to say.

In most cases where a cerebral lesion gives rise to paralysis, the most any electrical application can do is to keep the muscles alive and healthy until they become again subservient to the will.

With reference to treatment, intracranial lesions, giving rise to paralysis, may be divided into three groups. To the first group belong those lesions, traumatisms, hemorrhages, softenings (as the result of thromboses or embolisms), and neoplasms which do not invade motor regions of the brain, but by pressure on or irritation of contiguous or distant motor parts, produce a suspension of their function, thus giving rise to a temporary paralysis which vanishes when the irritation or pressure, whether as the result of treatment or spontaneously, disappears.

To the second group belong cases where the injury to the motor region of the brain is destructive but not progressive; as single wounds, hemorrhages, softenings, and where the consequent paralysis may ameliorate but never disappear.

In the third group are included cases where wounds excite a chronic inflammatory process,

or a new formation, which, by its extension or growth, gives rise to a progressively deepening paralysis, or where repeated hemorrhages, or embolisms, or thromboses, or a steadily growing tumor accomplish the same results.

In cases of the first group electricity hastens the happy issue ; in cases of the second group it decidedly ameliorates the condition of the patient ; in cases of the third group it is not indicated.

The commoner pathological processes which follow a cerebral lesion are as follows :

The injury when slight and reparable produces a partial or complete flaccid paralysis of certain muscles which, because of disuse, may diminish slightly in size. The descending irritative action of the cerebral lesion on the motor cells in the anterior horns of the spinal cord produces exaggerated reflex action and also increased electro-excitability. We thus find that both nerves and muscles respond to abnormally weak faradic and galvanic currents.

All these symptoms disappear with the removal of the cerebral lesion ; muscles, nerves, and spinal cord soon regain their healthy structure and function.

When the cerebral lesion is severer and irreparable, the paralysis is more decided and there ensues some general muscular wasting. After a varying period of time, there starts from the cerebral lesion a descending degeneration which travels down the lateral columns of the cord, implicating, more or less, the anterior horns of the cord and producing a neuro-muscular excitability which results in "contractures" of certain groups of muscles. In the course of the partial repair these severe cases of cerebral lesion undergo slight lessening of the paralysis, and a partial or complete relaxation of the contracture may occur. Reflexes are exaggerated and neuro-muscular electro-excitability is increased.

As a result of long-continued flaccid paralysis of cerebral origin the muscles waste away simply from disuse—not from any profound degenerative process,—while the substance of muscles in the state of contracture is gradually replaced by slightly extensible connective tissue, rendering the deformity permanent.

The treatment of muscles, the seat of a flaccid paralysis of cerebral origin, is a labile or

Of the sensory disturbances of cerebral origin mention will be made elsewhere.

LOCAL PARALYSES, as of lips, tongue, palate, pharynx, and larynx, are variously treated by electricity,—when of peripheral or medullary origin by local applications of galvanism—when of cerebral or hysterical origin by faradism—when of doubtful etiology by either,—using the current causing best contractions with the least discomfort. The success afforded by electricity, as an adjunct in the treatment of these cases, depends wholly on their pathology, those occurring in the course of hysteria yielding most readily.

Paralyses of OCULAR MUSCLES, external and internal, often present themselves for treatment. Here, too, the pathology of the case must be arrived at if possible. Faradism is not well borne about the eye, so galvanism is sometimes resorted to. An ascending current is generally used; the positive electrode, covered with a soft sponge, being held over the eye, the negative electrode being placed on the back of the neck.

So frequently is this treatment combined with medication, and so slow, as a general thing, is

improvement, that the real utility of the procedure is questionable.

Whether the faradic current penetrates deeply enough to affect the viscera of the great cavities is rather uncertain, still the occasional relief of constipation by faradization of the abdomen would tend to prove that it does reach deeply seated viscera in considerable quantities. This being a fact it may, and some assert it does, act well in cases of dilated stomach, enlarged spleen, etc., etc.

More localized applications are needed in the treatment of paralytic affections of the bladder, rectum, and uterus, after the expulsion of the fœtus. The current generally indicated in these cases is the faradic, one electrode of special shape being introduced into the cavity of the organ.

In cases of sudden failure of the heart, such as occurs in aconite and chloral poisoning, in addition to other stimulants, the free employment of the faradic brush with a strong current may help. A galvanic or faradic current, interrupted about sixty times to the minute, having one electrode on the precordium and the other

at the base of the neck or on the cervical spine, might excite a weak, over-distended heart to contraction.

In apœna, from opium, drowning, or ether, respiratory movements may generally be excited by faradizing the phrenic nerve in the neck or the respiratory muscles directly. This procedure may be used as an adjuvant to, not as a substitute for, ordinary artificial respiration.

SPASMODIC AFFECTIONS.

TONIC SPASMS, depending on a cerebral or spinal lesion, are not very amenable to direct electrical treatment, for the reason that the diseased condition is not in the muscles. Attempts to reach the seat of the lesion by galvanizing the head and back yield no better curative results. A speedy and decided relief of a contracture of supposed spinal or cerebral origin would lead me to doubt the correctness of the diagnosis. Nevertheless a trial might be made of a stabile galvanic current of bearable strength, the anode being on the contractured muscles, the cathode being on the spine. Gentle faradization of the opponent muscles might be tried also.

Contractured muscles in hysterical subjects are occasionally relaxed by stabile galvanic applications, occasionally by faradization of antagonistic muscles. More often these cases resist electrical treatment of any kind, yielding perhaps to metallo-therapy or magnetism.

Tonic spasms of doubtful pathology, such as are frequently seen in muscles of the face and neck, sometimes yield to repeated stabile applications of galvanism, very rarely to one or two applications. As a general thing the anode should be placed on the contractured muscle.

Clonic spasmodic affections, as a rule, are little benefited by electricity. Many of them, as, for instance, the rhythmical tremor of paralysis agitans, are temporarily stopped by galvanism. If the anode be placed in the trembling hand and the cathode on the back of the neck, a bearable current will soon lessen, and often entirely check, the tremor. A prolongation or repetition of this application, however, is attended by no curative results.

Spasmodic affections, complicated by muscular weakness and sensory disturbances, such as writer's cramp, are not much helped by electrical treatment.

Spasm of the various viscera (bladder, uterus, intestines) *may* yield to galvanism passed continuously and diffusely through them, but will more likely do so if more localized applications are made by especially constructed electrodes.

SENSORY DISTURBANCES.

Loss of sensibility, or ANÆSTHESIA, due to a cerebral or spinal lesion, occasionally improves or disappears under the use of the faradic brush; anæsthesias of peripheral origin are still more apt to yield, while the anæsthesia or hemianæsthesia occurring in hysterical subjects sometimes is cured like magic.

The part brushed must be dry, hence it is advisable generally to lightly powder the part; fine flour or chalk will do.

ANALGESIA, or insensibility to pain, whether organic (depending on some central lesion) or functional (as occurring in hysteria), sometimes improves or disappears under the employment of the faradic brush. More often it resists this, and, like anæsthesia, more often yields to the subtler action of metals or magnets; particularly is this true of an hysterical analgesia.

HYPERÆSTHESIA from any cause *may* yield to a stabile galvanic application; good results more often following an application of the anode to the hyperæsthetic point.

PARÆSTHESIAS of different varieties may be benefited by electrical treatment of various sorts; but the fact that the means employed and the results obtained are so diverse and contradictory, convinces us that expectant attention has much to do with the cure.

PAINS of a cerebral origin or from disease of the spinal cord (as in sclerosis of the posterior columns) are not amenable to electrical treatment. When caused by acute neuritis also, other remedies are much more indicated than electricity.

Some pains, dependent on chronic neuritis, and more, of doubtful pathology, are relieved, a few cured, by galvanism. As a rule, best results follow stabile application with the anode over the painful point, or stroked slowly over the painful region. Successful results depend principally on the functional nature of the pain or its dependence on a trivial lesion.

When caused or accompanied by spasm of

various viscera (uterus, bladder, bowels), relief of pain is sometimes afforded by stabile galvanic applications, passed diffusely through the organs or locally applied by means of specially constructed electrodes.

Relief, following electrical applications, in pain of obscure causation, often comes from expectant attention, as is proved by the magical effects which often follow the application of electrodes entirely devoid of electricity.

General mild faradic or galvanic applications often relieve restlessness and insomnia when arising from trivial causes.

Some TROPHIC DISTURBANCES, such as bed-sores or ordinary sluggish ulcers, are benefited by gentle stabile galvanic currents. A continuous but *very* weak current may be kept up for days by connecting pieces of zinc and silver by a rheophore, placing one or the other over the ulcer, the other on some adjacent part. There is a doubt of course in this instance whether the electricity or the pressure of the plate effects the cure.

CHRONIC RHEUMATISM, RHEUMATIC ARTHRITIS, and ARTHRITIS DEFORMANS are often helped and

sometimes completely stayed by stabile galvanic applications. As these cases are seldom treated by electricity alone, but also by massage, passive movements, and often internal medication, the exact utility of galvanism is doubtful.

Electricity may be used as a COUNTERIRRITANT in various ways. The faradic current, applied by means of a wire brush, produces a very profound but transitory impression, on sensory nerves.

By a labile galvanic application with a strong current an active cutaneous hyperæmia may be induced in any desired locality. By a stabile galvanic application any trophic change, from hyperæmia, sudamina, and vesication to sloughing, may be produced, according to the length and strength of the application. Thus it might be used as a rubefacient, an epispastic, or an escharotic.

As an escharotic it is generally applied directly to the tissue to be acted on by means of an uncovered electrode, generally a needle or a set of needles. This constitutes the procedure known as ELECTROLYSIS, and is sometimes employed for the destruction of tumors, gen-

erally of a vascular nature, including aneurisms. The methods of electrolysis differ only in the fact that in some cases one pole of the battery is connected with a wet sponge-covered electrode, which is placed on some neighboring point of the body, while the other pole terminates in needles, which are thrust into the morbid tissue; while in other cases both poles terminate in needles.

A battery of a few *large* cells is most efficient for electrolysis. There are very few cases in which its use cannot be better dispensed with, and cleaner, more-surgical procedures employed.

By conducting a strong current through a short platinum wire a white heat can be obtained, and all the requirements of an actual cautery are fulfilled. For use as a counter-irritant to the skin it is much inferior to the benzine-heated cautery for many reasons: it is very much more expensive, troublesome, and bulky; it very easily gets out of order; and by electricity it is impossible to heat the large surface of platinum, so necessary in many instances, and which can be heated in any shape or size by gas or vapor of benzine. To check hemorrhage it has not a single advantage over

the benzine cautery. For the extirpation of tumors, etc., the galvano-cautery has these two advantages: in it we can combine in one instrument a cautery and an écraseur; and a narrower, more delicate cautery-knife can be heated by the galvanic current than by an inflammable vapor. In every other respect the gas cautery is just as efficient.

I think I only echo the opinion of the best surgeons when I say that the galvano-cautery should supplant cleaner and more-surgical procedures only when the site of the operation is too inaccessible for concise dissection or hemostasis.

Peculiarly constructed batteries are needed for galvano-cautery. They should consist of from two to six cells containing very large elements located very near together. The liquid should be more corrosive than in an ordinary battery.

In a cell of this construction polarization is very apt to take place. This is prevented in some batteries by giving a swinging motion to the elements, or by forcing air occasionally between the plates and dislodging the bubbles of oxygen and hydrogen.

INDEX.

NAME	DATE DUE